E-20-J37

Applying MathCad to the Highway Capacity Manual

(Contract Number - DTRS-57-97-C-00065)

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Signalized Intersections

Input Worksheet

General Information

Analyst: Analyst:
Agency or Company: Agency or Company
Date Performed: Date Performed
Analyst Time Period: Analyst Time Period

Site Information

Intersection: Intersection
Area Type: (•) CBD ( ) Other
Jurisdiction: Jurisdiction
Analysis Year: Analysis Year

Intersection Geometry

	EB	WB	NB	SB
Number of lanes	2	2	1	1
Width of each lane (ft)	11	11	15	15
Number of shared Right-turn lanes	1	1	1	1
Number of shared Left-turn lanes	1	1	1	1
Number of exclusive Left-turn lanes	0	0	0	0
Exclusive Left-turn lane width (ft)	0	0	0	0
Grade (%)	0	0	0	0

	EW	NS
Crosswalk length (ft)	44	30
Effective crosswalk width (ft)	10	10

Volume and Timing Input

	EB			WB			NB			SB		
	LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT
Volume, V (veh/h)	65	620	35	30	700	20	30	370	20	40	510	50
% heavy vehicles, %HV	5	5	5	5	5	5	8	8	8	8	8	8
Peak-hour factor, PHF	0	0.9	0	0	0.9	0	0	0.9	0	0	0.9	0
Pretimed (1) or actuated (2)	0	1	0	0	1	0	0	1	0	0	1	0
Start-up time, l_1 (s)	0	0	0	0	0	0	0	0	0	0	0	0
Extension of effective green time, e (s)	0	0	0	0	0	0	0	0	0	0	0	0
Arrival Type, AT	0	4	0	0	2	0	0	3	0	0	3	0

	EB	WB	NB	SB
Approach pedestrian volume, V_{ped} (p/h)	100	100	100	100
Approach bicycle volume, V_{bic} (bicycles/h)	20	20	20	20
Parking, Yes (1) or No (2)	2	2	2	2
Parking maneuvers, N_m (maneuvers/h)	0	0	0	0
Bus stopping, N_b (buses/h)	0	0	0	0

Signal Phasing Plan

	1	2	3	4	5	6	7	8
Timing G =	26	36	0					
Y =	4	4	0					

Unit extension	0	0	0					

The table for the unit extension assignment is additional to the HCM Input Worksheet. The unit extension is used to compute the Incremental Delay Calibration Factor, k.

Cycle length $C := 70s$

	EB	WB	NB	SB
Min. timing for pedestrians, G_p (s)	11.2	11.2	14.7	14.7

$G_p^T =$

Additional Information

Information needed to perform some computations and that is not defined in the HCM Input Worksheet.

Base saturation flow rate (pc/h/ln) $s_0 := 1900$

Passenger-car equivalent (pc/HV) $E_T := 2$

Lane Utilization Adjustment Factor

	EB	WB	NB	SB
Lane utilization factor	0.95	0.95	1	1

Left-turn Adjustment Factor

	EB	WB	NB	SB
Left-turn adjustment case	5	5	5	5
Single-Lane (1) or Multilane (2) approach	2	2	1	1
Proportion of left turns using protected phase, P_{LTA}	0	0	0	0
If Left-turn adjustment case is 3 or 6: protected + permitted (1) or permitted + protected (2)	0	0	0	0

Right-turn Adjustment Factor

	EB	WB	NB	SB
Exclusive (1), Shared (2) or Single lane (3)	2	2	2	2
Proportion of right turns using protected phase, P_{RTA}	0	0	0	0

Control Delay

Duration of analysis period (h) $T := 0.25$

Initial queue at the start of period T (veh) $Q_b := 0$

Upstream filtering metering adjustment factor $I := 1$

Lane Group

		EB			WB			NB			SB		
		LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT
	1	1	1	1	0	0	0	0	0	0	0	0	0
	2	0	0	0	2	2	2	0	0	0	0	0	0
	3	0	0	0	0	0	0	3	3	3	0	0	0
	4	0	0	0	0	0	0	0	0	0	4	4	4
Group	5	0	0	0	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	0	0	0
	7	0	0	0	0	0	0	0	0	0	0	0	0
	8	0	0	0	0	0	0	0	0	0	0	0	0
	9	0	0	0	0	0	0	0	0	0	0	0	0
	10	0	0	0	0	0	0	0	0	0	0	0	0

Phase Number	1	1	1	1	1	1	2	2	2	2	2	2
	0	0	0	0	0	0	0	0	0	0	0	0

- These tables are used to define Lanes Groups and to assign a Phase to each lane group.
- The table to assign the phase has two rows in case of two phases are assigned to the same lane group.
- If the left turn case is 3 or 6, protected-plus-permitted phasing, the protected phase must be assigned in the first row and the permitted phase in the second row. For the lane group assignment, the lane group for the protected phase must be assigned first than the lane group for the permitted phase.

Supplemental Worksheet for Permitted Left Turns Opposed by Single-Lane Approach

General Information

Project Description: Project Description

Input

Input	EB	WB	NB	SB
Total actual green time for LT lane group, G(s)	0	0	36	36
Effective permitted green time for LT lane group, g(s)	0	0	36	36
Opposing effective green time, g_0 (s)	0	0	36	36
Number of lanes in LT lane group, N	0	0	1	1
Lost time for LT lane group, t_L	0	0	4	4

Computation

Adjusted LT flow rate, v_{LT} (veh/h)	0	0	33	44
Proportion of LT volume in LT lane group, P_{LT}	0	0	0.071	0.066
Proportion of LT volume in opposing flow, P_{LTo}	0	0	0.066	0.071
Adjusted flow rate for opposing approach, v_o (veh/h)	0	0	667	466
LT (left turns) volume per cycle, LTC	0	0	0.642	0.856
Opposing flow per lane, per cycle, v_{olc} *(veh/C/ln)*	0	0	12.969	9.061
Opposing platoon ratio, R_{po}	0	0	1	1
Portion of green time, TH veh not be blocked by LT veh. g_f (s)	0	0	14.783	12.509
Opposing queue ratio, q_{ro}	0	0	0.486	0.486
Portion of green time blocked by a queue of opp. veh, g_q (s)	0	0	12.191	8.32
Portion of green time not block. by a queue of opp. veh. g_u (s)	0	0	21.217	23.491
Max num of opp. veh. that could arrive during g_{diff}, n	0	0	0	0
Proportion of TH and RT vehicles, P_{THo}	0	0	0.934	0.929
Through-car equiv. for permitted LT, E_{L1}	0	0	2.7	2.2
Through-car equiv. for opp. mov. of permitted LT, E_{L2}	0	0	1	1
Minimum left-turn adjustment factor, f_{min}	0	0	0.059	0.059
Max(g_q - g_f, 0), g_{diff}	0	0	0	0
Left-turn adjustment factor, f_{LT}	0	0	0.937	0.952

Results_{SL} =

Notes

v_{LT}, P_{LT}, P_{LTo} and v_o are shown in the Computation Section of the Worksheet, not in the Input Section as in the HCM. These values are computed by the worksheet; hence they don't need to be input manually.

Supplemental Worksheet for Permitted Left Turns Opposed by Multilane Approach

General Information

Project Description: Project Description

Input

Input	EB	WB	NB	SB
Total actual green time for LT lane group, G(s)	26	26	0	0
Effective permitted green time for LT lane group, g(s)	26	26	0	0
Opposing effective green time, g_0 (s)	26	26	0	0
Number of lanes in LT lane group, N	2	2	0	0
Number of lanes in opposing approach, N_o	2	2	0	0
Lost time for LT lane group, t_L	4	4	0	0

Computation

Adjusted LT flow rate, v_{LT} (veh/h)	72	33	0	0
Proportion of LT volume in LT lane group, P_{LT}	0.09	0.04	0	0
Adjusted flow rate for opposing approach, v_o (veh/h)	833	800	0	0
LT (left turn) volume per cycle, LTC	1.4	0.642	0	0
Opposing lane utilization factor, f_{LUo}	0.95	0.95	0	0
Opposing flow per lane, per cycle, v_{olc} (veh/C/ln)	8.525	8.187	0	0
Portion of green time, TH veh not be blocked by LT veh. g_f (s)	4.461	9.687	0	0
Opposing platoon ratio, R_{po}	0.667	1.333	0	0
Opposing queue ratio, q_{ro}	0.752	0.505	0	0
Portion of green time blocked by a queue of opp. veh, g_q (s)	11.314	8.013	0	0
Portion of green time not block. by a queue of opp. veh. g_u (s)	14.686	16.313	0	0
Through-car equiv. for permitted LT, E_{L1}	3.3	3.2	0	0
Proportion of left turns in shared lane, P_L	0.268	0.094	0	0
Minimum left-turn adjustment factor, f_{min}	0.098	0.084	0	0
LT adjust. factor applied only to left-turn lane, f_m	0.521	0.893	0	0
Left-turn adjustment factor, f_{LT}	0.716	0.901	0	0

Results_{ML} =

Notes

v_{LT}, P_{LT}, and v_o are shown in the Computation Section of the Worksheet, not in the Input Section as in the HCM. These values are computed by the worksheet; hence they don't need to be input manually.

Supplemental Worksheet for Pedestrian-Bicycle Effects On Permitted Left Turns and Right Turns

General Information

Project Description: Project Description

Permitted Left Turns

	EB	WB	NB	SB
Effective pedestrian green time, g_p (s)	26	26	36	36
Conflicting pedestrian volume, v_{ped} (p/h)	100	100	100	100
Pedestrian flow rate, v_{pedg}	269	269	194	194
Average pedestrian occupancy, OCC_{pedg}	0.135	0.135	0.097	0.097
Opposing queue clearing time, g_q (s)	11.314	8.013	12.191	8.32
Effec. pedes. green consumed by oppos. veh. queue	0.435	0.308	0.339	0.231
Pedestrian occupancy after the opposing queue clears	0.105	0.114	0.081	0.086
Opposing flow rate, v_o (veh/h)	833	800	667	466
Relevant occupancy, OCC_r	0.033	0.037	0.032	0.045
Number of cross-street receiving lanes, N_{rec}	1	1	2	2
Number of turning lanes, N_{turn}	1	1	1	1
Permitted phase adjust. pedes./bicycle blockage, A_{pbT}	0.967	0.963	0.981	0.973
Proportion of left turns, P_{LT}	0.09	0.04	0.071	0.066
Proportion of left turns using protected phase, P_{LTA}	0	0	0	0
Pedestrian adjustment factor, f_{Lpb}	0.997	0.999	0.999	0.998

$Results_{PBLT}$ =

Permitted Right Turns

	EB	WB	NB	SB
Effective pedestrian green time, g_p (s)	26	26	36	36
Conflicting pedestrian volume, v_{ped} (p/h)	100	100	100	100
Conflicting bicycle volume, v_{bic} (bicycles/h)	20	20	20	20
Pedestrian flow rate, v_{pedg}	269	269	194	194
Average pedestrian occupancy, OCC_{pedg}	0.135	0.135	0.097	0.097
Effective green, g (s)	26	26	36	36
Bicycle flow rate, v_{bicg}	54	54	39	39
Bicycle conflict zone occupancy, OCC_{bicg}	0.04	0.04	0.034	0.034
Relevant occupancy, OCC_r	0.169	0.169	0.128	0.128
Number of cross-street receiving lanes, N_{rec}	1	1	2	2
Number of turning lanes, N_{turn}	1	1	1	1
Permitted phase adjust. pedes./bicycle blockage, A_{pbT}	0.831	0.831	0.923	0.923
Proportion of right turns, P_{RT}	0.049	0.026	0.047	0.084
Proportion of right turns using protected phase P_{RTA}	0	0	0	0
Pedestrian-bicycle adjustment factor, f_{Rpb}	0.992	0.996	0.996	0.994

$Results_{PBRT}$ =

Volume Adjustment and Saturation Flow Rate Worksheet

General Information

Project Description: Project Description

Volume Adjustment

	EB			WB			NB			SB		
	LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT
Volume, V (veh/h)	65	620	35	30	700	20	30	370	20	40	510	50
Peak-hour factor, PHF	0	0.9	0	0	0.9	0	0	0.9	0	0	0.9	0
Adjusted flow rate, v_p=V/PHF (veh/h)	72	689	39	33	778	22	33	411	22	44	567	56
Adjusted flow rate in lane group, v (veh/h)	0	800	0	0	833	0	0	466	0	0	667	0
Proportion of LT or RT (P_{LT} or P_{RT})	0.09	0	0.049	0.04	0	0.026	0.071	0	0.047	0.066	0	0.084

Results_{VA} =

Saturation Flow Rate (*see Exhibit 16-7 to determine adjustment factors*)

	EB			WB			NB			SB		
	LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT
Base saturation flow, s_o (pc/h/ln)	0	1900	0	0	1900	0	0	1900	0	0	1900	0
Number of lanes, N	0	2	0	0	2	0	0	1	0	0	1	0
Lane width adjustment factor, f_w	0	0.967	0	0	0.967	0	0	1.1	0	0	1.1	0
Heavy-vehicle adjustment factor, f_{HV}	0	0.952	0	0	0.952	0	0	0.926	0	0	0.926	0
Grade adjustment factor, f_g	0	1	0	0	1	0	0	1	0	0	1	0
Parking adjustment factor, f_p	0	1	0	0	1	0	0	1	0	0	1	0
Bus blockage adjustment factor, f_{bb}	0	1	0	0	1	0	0	1	0	0	1	0
Area type adjustment factor, f_a	0	0.9	0	0	0.9	0	0	0.9	0	0	0.9	0
Lane utilization adjustment factor, f_{LU}	0	0.95	0	0	0.95	0	0	1	0	0	1	0
Left-turn adjustment factor, f_{LT}	0	0.716	0	0	0.901	0	0	0.937	0	0	0.952	0
Right-turn adjustment factor, f_{RT}	0	0.993	0	0	0.996	0	0	0.993	0	0	0.987	0
Left-turn ped/bike adjust. factor, f_{Lpb}	0	0.997	0	0	0.999	0	0	0.999	0	0	0.998	0
Right-turn ped/bike adjust. factor, f_{Rpb}	0	0.992	0	0	0.996	0	0	0.996	0	0	0.994	0
Adjusted saturation flow, s (veh/h)	0	2101	0	0	2669	0	0	1612	0	0	1624	0

Results_{SFR} =

Capacity and LOS Worksheet

General Information

Project Description: Project Description

Capacity Analysis

Phase number	1	1	2	2
Lane group	1	2	3	4
Adjusted flow rate, v (veh/h)	800	833	466	667
Saturation flow rate, s (veh/h)	2101	2669	1612	1624
Lost time, t_L (s)	4	4	4	4
Effective green time, g(s)	26	26	36	36
Green ratio, g/C	0.371	0.371	0.514	0.514
Lane group capacity, c (veh/h)	780	991	829	835
v/c ratio, X	1.026	0.841	0.562	0.799
Flow ratio, v/s	0.381	0	0	0.411
Critical lane group/phase (1)	1	0	0	1

ResultsCapacity =

Sum of flow ratios for critical lanes groups: $Y_c = 0.791$

Total lost time per cycle: $L = 8$ s

Critical flow rate to capacity ratio: $X_c = 0.894$

Lane Group Capacity, Control Delay, and LOS Determination

	EB			WB			NB			SB		
	LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT
Adjusted flow rate, v (veh/h)	0	800	0	0	833	0	0	466	0	0	667	0
Lane group capacity, c (veh/h)	0	780	0	0	991	0	0	829	0	0	835	0
v/c ratio, X	0	1.026	0	0	0.841	0	0	0.562	0	0	0.799	0
Total green ratio, g/C	0	0.371	0	0	0.371	0	0	0.514	0	0	0.514	0
Uniform delay, d_1 (s/veh)	0	22	0	0	20.106	0	0	11.615	0	0	14.014	0
Incremental delay calibration, k	0	0.5	0	0	0.5	0	0	0.5	0	0	0.5	0
Incremental delay, d_2 (s/veh)	0	38.911	0	0	8.556	0	0	2.749	0	0	7.874	0
Initial queue delay, d_3 (s/veh)	0	0	0	0	0	0	0	0	0	0	0	0
Progression adjustment factor, PF	0	0.924	0	0	1.113	0	0	1	0	0	1	0
Delay, d (s/veh)	0	59.2	0	0	30.9	0	0	14.4	0	0	21.9	0
LOS by lane group	0	"E"	0	0	"C"	0	0	"B"	0	0	"C"	0

LOS_1 =

Delay by approach, d_A (s/veh)	59.2	30.9	14.4	21.9
LOS by approach	"E"	"C"	"B"	"C"
Approach flow rate, v_A (veh/h)	800	833	466	667

LOS_2 =

Intersection delay (s/veh) $d_I = 34.1$

Intersection LOS LOS_I = "C"

Supplemental Uniform Delay Worksheet for Left Turns from Exclusive Lanes with Protected and Permitted Phases

General Information

Project Description: Project Description

v/c Ratio Computation

	EB	WB	NB	SB
Protected phase effective green interval, g (s)	0	0	0	0
Opposing queue effective green interval, g_q (s)	0	0	0	0
Unopposed green interval, g_u (s)	0	0	0	0
Red time, r(s)	0	0	0	0
Arrival rate, q_a (veh/s)	0	0	0	0
Protected phase departure, s_p (veh/s)	0	0	0	0
Permitted phase departure, s_s (veh/s)	0	0	0	0
v/c ratio, X_{perm}	0	0	0	0
v/c ratio, X_{prot}	0	0	0	0

$Results_{vcratio} =$

Uniform Queue Size and Delay Computations

	EB	WB	NB	SB
Queue at beginning of green arrow, Q_a	0	0	0	0
Queue at beginning of unsaturated green, Q_u	0	0	0	0
Residual queue, Q_r	0	0	0	0
Uniform delay, d_1	0	0	0	0

$Results_{delay} =$

TWSC - Unsignalized Intersections

Worksheet 1

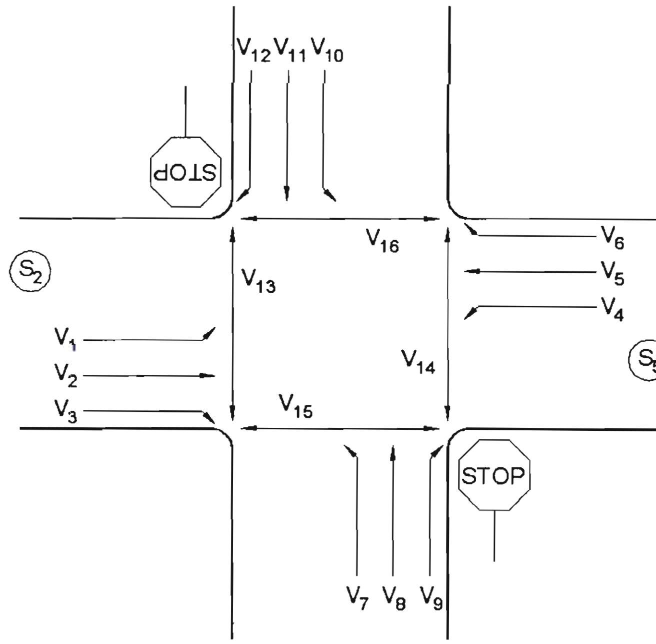
General Information

Analyst: Analyst
Agency or Company: Agency or Company
Date Performed: Date Performed
Analyst Time Period: Analyst Time Period

Site Information

Intersection: Intersection
Jurisdiction: Jurisdiction
Analysis Year: Analysis Year

Geometrics and Movements



Number of lanes in major street 2

Length of study period $T := 0.25 \text{hr}$

Median type Undivided

Movement	8	11	7	10
Single stage (1) or Two stage (2)	1	1	1	1

Worksheet 2

Vehicle Volumes and Adjustments

Vehicle Volumes and Adjustments

Movement	1	2	3	4	5	6	7	8	9	10	11	12
Volume (veh/h)	0	250	40	150	300	0	40	0	120	0	0	0
Peak-hour factor, PHF	0	1	1	1	1	0	1	0	1	0	0	0
Proportion of heavy vehicles, P_{HV}	0	0.1	0.1	0.1	0.1	0	0.1	0	0.1	0	0	0

Hourly flow rate (veh/h) $v_h^T =$

0	250	40	150	300	0	40	0	120	0	0	0

Pedestrian Volumes and Adjustments

Movement	13	14	15	16
Flow, V_x (ped/h)	0	0	0	0
Lane width, w (ft)	0	0	0	0
Walking speed[1], S_p (ft/s)	0	0	0	0

1. Default walking speed = 4.0 ft/s

Percent blockage, f_p (Equation 17-11) $f_p^T =$

0	0	0	0

TWSC Unsignalized Intersections

Worksheet 3

General Information

Project Description: Project Description

Lane Designation

Movements	Lane 1			Lane 2			Lane 3			Grade, G	Right Turn [1] Channelized?
1, 2, 3	2	3	0	0	0	0	0	0	0	0	1
4, 5, 6	4	0	0	5	0	0	0	0	0	0	1
7, 8, 9	7	9	0	0	0	0	0	0	0	0	1
10, 11, 12	0	0	0	0	0	0	0	0	0	0	0

There are 3 columns for each lane

1. No (1) or Yes (2)

Flared Minor-Street Approach

Movement 9 ○ Yes ◉ No Storage space $n_9 := 0$ (number of vehicles)

Movement 12 ○ Yes ◉ No Storage space $n_{12} := 0$ (number of vehicles)

Median Storage*

* Includes raised or striped median (RM), or two-way left-turn lane (TWLTL)

Type

Movement 7 and 8 ○ Yes ◉ No Storage space $m_{78} := 0$ (number of vehicles)

Movement 10 and 11 ○ Yes ◉ No Storage space $m_{1011} := 0$ (number of vehicles)

Upstream Signals

Movements		Distance to Signal, D (ft)	Prog Speed, S_{prog} (mi/h)	Cycle Length, C (s)	Green Time g_{eff} (s)	Arrival Type	Saturation Flow Rate, s (veh/h)	Progressed Flow V_{prog} (veh/h)
S_2	protected LT	0	0	0	0	3	0	0
	TH	0	0	0	0	0	0	0
S_5	protected LT	0	0	0	0	3	0	0
	TH	0	0	0	0	0	0	0

Computing Delay to Major-Street Vehicles

Data for Computing Effect of Delay to Major-Street Vehicles

	S_2 Approach	S_5 Approach
Shared-lane volume, major-street through vehicles, v_{i1} blocked by LT	0	0
Shared-lane volume, major-street right-turn vehicles, v_{i2} blocked by LT	0	0
Saturation flow rate, major-street through vehicles, s_{i1}	0	0
Saturation flow rate, major-street right-turn vehicles, s_{i2}	0	0
Number of major-street through lanes	0	0
Length of study period, T (h)	0	0

TWSC Unsignalized Intersections

Worksheet 4

General Information

Project Description: Project Description

Critical Gap and Follow-Up Time

Movement		Major LT 1	4	Minor RT 9	12	Minor TH 8	11	Minor LT 7	10
$t_{c,base}$ (Exhibit 17-5)		0	4.1	6.2	0	0	0	7.1	0
$t_{c,HV}$		0	1	1	0	0	0	1	0
P_{HV} (from Worksheet 2)		0	0.1	0.1	0	0	0	0.1	0
$t_{c,G}$		0	0	0.1	0	0	0	0.2	0
G (from Worksheet 3)		0	0	0	0	0	0	0	0
$t_{3,LT}$		0	0	0	0	0	0	0.7	0
$t_{c,T}$	single stage	0	0	0	0	0	0	0	0
	two stage	0	0	0	0	0	0	0	0
t_c (Eq. 17-1)	single stage	0	4.2	6.3	0	0	0	6.5	0
	two stage	0	0	0	0	0	0	0	0

Results_{tc} =

Movement	Major LT 1	4	Minor RT 9	12	Minor TH 8	11	Minor LT 7	10
$t_{f,base}$ (Exhibit 17-5)	0	2.2	3.3	0	0	0	3.5	0
t_{fHV}	0	0.9	0.9	0	0	0	0.9	0
P_{HV} (from Worksheet 2)	0	0.1	0.1	0	0	0	0.1	0
t_f (Equation 17-2)	0	2.29	3.39	0	0	0	3.59	0

Results_{tf} =

Worksheet 5a

Time to Clear Standing Queue (Computation 1)

	Movement 2 $V_{T,prog}$	$V_{L,prot}$	Movement 5 $V_{T,prog}$	$V_{L,prot}$
Effective green, g_{eff} (s)	0	0	0	0
Cycle length, C (s)	0	0	0	0
Saturation flow rate, s (veh/h)	0	0	0	0
Arrival type	0	3	0	3
Progressed flow, v_{prog} (veh/h)	0	0	0	0
R_p (from Chapter 16)	0	1	0	1
Prop. of veh. arriving on green, P	0	0	0	0
g_{q1} (Equation 17-18)	0	0	0	0
g_{q2} (Equation 17-19)	0	0	0	0
g_q (Equation 17-20)	0	0	0	0

Results_{5a} =

TWSC Unsignalized Intersections

Worksheet 5b

General Information

Project Description: Project Description

Proportion of Time TWSC Intersection is Blocked (Computation 2)

	Movement 2		Movement 5	
	$V_{T,prog}$	$V_{L,prot}$	$V_{T,prog}$	$V_{L,prot}$
α (Exhibit 17-13)	0		0	
$\beta = (1 - \alpha)^{-1}$	0		0	
$t_a = D/S_{prog}$ (s)	0		0	
$F = (1+\alpha\beta t_a)^{-1}$	0		0	

Results$_{5b1}$ =

$f = v_{prog}/vc \geq 0$	0	0	0	0
$v_{c,max}$ (Equation 17-21)	0	0	0	0
$v_{c,min}$ = 1000N	0	0	0	0
t_p (Equation 17-22)	0	0	0	0

Results$_{5b2}$ =

p (Equation 17-23)	p^T =	0	0

Worksheet 5c

Platoon Event Periods (Computation 3)

p_2 (from Worksheet 5b)	0
p_5 (from Worksheet 5b)	0
p_{dom} (Equation 17-24)	0
p_{subo} (Equation 17-25)	0
Constrained or unconstrained (Equation 17-26, 17-27)	0

Results5c1 =

Proportion for Minor Movements, p_x

	Single-Stage (Exhibit 17-16)	Two-Stage Stage I	Two-Stage Stage II
p_1	0	0	0
p_4	0	0	0
p_7	0	0	0
p_8	0	0	0
p_9	0	0	0
p_{10}	0	0	0
p_{11}	0	0	0
p_{12}	0	0	0

Results5c2 =

TWSC Unsignalized Intersections

Worksheet 5d

General Information

Project Description: Project Description

Conflicting Flows During Unblocked Period (Computation 4)

Single-Stage

Movements	1	4	7	8	9	10	11	12
$v_{c,x}$ (Exhibit 17-4)	0	0	0	0	0	0	0	0
s (veh/h)	0	0	0	0	0	0	0	0
p_x (from Worksheet 5c)	0	0	0	0	0	0	0	0
$v_{c,u,x}$ (Equation 17-28)	0	0	0	0	0	0	0	0

Results_{5d1} =

Two-Stage

Movements	7		8		10		11	
	Stage I	Stage II	Stage I	Stage II	Stage I	Stage II	Stage I	Stage II
$v_{c,x}$ (Exhibit 17-4)	0	0	0	0	0	0	0	0
s (veh/h)	0	0	0	0	0	0	0	0
p_x (from Worksheet 5c)	0	0	0	0	0	0	0	0
$v_{c,u,x}$ (Equation 17-28)	0	0	0	0	0	0	0	0

Results_{5d2} =

Worksheet 5e

Capacity During Unblocked Period (Computation 5)

Single-Stage

Movements	1	4	7	8	9	10	11	12
p_x (from Worksheet 5c)	0	0	0	0	0	0	0	0
$c_{r,x}$ (Equation 17-3)	0	0	0	0	0	0	0	0
$c_{plat,x}$ (Equation 17-29)	0	0	0	0	0	0	0	0

Results_{5e1} =

Two-Stage

Movements	7		8		10		11	
	Stage I	Stage II	Stage I	Stage II	Stage I	Stage II	Stage I	Stage II
p_x (from Worksheet 5c)	0	0	0	0	0	0	0	0
$c_{r,x}$ (Equation 17-3)	0	0	0	0	0	0	0	0
$c_{plat,x}$ (Equation 17-29)	0	0	0	0	0	0	0	0

Results_{5e2} =

TWSC Unsignalized Intersections

Worksheet 6

General Information

Project Description: Project Description

Impedance and Capacity Calculation

Step 1: RT from Minor Street	v_9	v_{12}
Conflicting flows (Exhibit 17-4)	$V_{c9} = 270$	$V_{c12} = 0$
Potential capacity (Equation 17-3 or 17-29)	$c_{p9} = 750$	$c_{p12} = 0$
Ped impedance factor (Equation 17-12)	$p_{p9} = 1$	$p_{p12} = 0$
Movement capacity (Equation 17-4)	$c_{m9} = 750$	$c_{m12} = 0$
Prob of queue-free state (Equation 17-5)	$p_{09} = 0.84$	$p_{012} = 1$

Step 2: LT from Major Street	v_4	v_1
Conflicting flows (Exhibit 17-4)	$V_{c4} = 290$	$V_{c1} = 0$
Potential capacity (Equation 17-3 or 17-29)	$c_{p4} = 1227$	$c_{p1} = 0$
Ped impedance factor (Equation 17-12)	$p_{p4} = 1$	$p_{p1} = 0$
Movement capacity (Equation 17-4)	$c_{m4} = 1227$	$c_{m1} = 0$
Prob of queue-free state (Equation 17-5)	$p_{04} = 0.878$	$p_{01} = 1$
Major left shared lane prob of queue-free state (Equation 17-16)	$pp_{04} = 0$	$pp_{01} = 0$

Step 3: TH from Minor Street (4-leg intersections only)	v_8	v_{11}
Conflicting flows (Exhibit 17-4)	$V_{c8} = 0$	$V_{c11} = 0$
Potential capacity (Equation 17-3 or 17-29)	$c_{p8} = 0$	$c_{p11} = 0$
Ped impedance factor (Equation 17-12)	$p_{p8} = 0$	$p_{p11} = 0$
Capacity adjustment factor due to impeding mov. (Equation 17-13)	$f_8 = 0$	$f_{11} = 0$
Movement capacity (Equation 17-7)	$c_{m8} = 0$	$c_{m11} = 0$
Prob of queue-free state (Equation 17-5)	$p_{08} = 0$	$p_{011} = 0$

Step 4: LT from Minor Street (4-leg intersections only)	v_7	v_{10}
Conflicting flows (Exhibit 17-4)	$v_{c74} = 0$	$v_{c104} = 0$
Potential capacity (Equation 17-3 or 17-29)	$c_{p7} = 0$	$c_{p10} = 0$
Ped impedance factor (Equation 17-12)	$p_{p7} = 0$	$p_{p10} = 0$
Major left, minor through impedance factor	$p''_7 = 0$	$p''_{10} = 0$
Major left, minor through adjusted impedance factor (Equation 17-8)	$p'_7 = 0$	$p'_{10} = 0$
Capacity adjustment factor due to impeding mov. (Equation 17-14)	$f_7 = 0$	$f_{10} = 0$
Movement capacity (Equation 17-10)	$c_{m74} = 0$	$c_{m104} = 0$

Step 5: LT from Minor Street (T-intersections only)	v_7	v_{10}
Conflicting flows (Exhibit 17-4)	$v_{c75} = 870$	$v_{c105} = 0$
Potential capacity (Equation 17-3 or 17-29)	$c_{p75} = 312$	$c_{p105} = 0$
Ped impedance factor (Equation 17-12)	$p_{p75} = 1$	$p_{p105} = 0$
Capacity adjustment factor due to impeding mov. (Equation 17-13)	$f_{75} = 0.878$	$f_{105} = 0$
Movement capacity (Equation 17-7)	$c_{m75} = 274$	$c_{m105} = 0$

TWSC Unsignalized Intersections

Worksheet 7a

General Information

Project Description: Project Description

Effect of Two-Stage Gap Acceptance

Step 3: TH from Minor Street	v_8	v_{11}
Part I - First Stage		
Conflicting flows (Exhibit 17-4)	$v_{cI8} = 0$	$v_{cI11} = 0$
Potential capacity (Equation 17-3 or 17-29)	$c_{pI8} = 0$	$c_{pI11} = 0$
Ped impedance factor (Equation 17-12)	$p_{pI8} = 0$	$p_{pI11} = 0$
Capacity adjustment factor due to impeding movement (Equation 17-6 or 17-13)	$f_{I8} = 0$	$f_{I11} = 0$
Movement capacity (Equation 17-7)	$c_{mI8} = 0$	$c_{mI11} = 0$
Prob of queue-free state (Equation 17-5)	$p_{0I8} = 0$	$p_{0I11} = 0$
Part II - Second Stage		
Conflicting flows (Exhibit 17-4)	$v_{cII8} = 0$	$v_{cII11} = 0$
Potential capacity (Equation 17-3 or 17-29)	$c_{pII8} = 0$	$c_{pII11} = 0$
Ped impedance factor (Equation 17-12)	$p_{pII8} = 0$	$p_{pII11} = 0$
Capacity adjustment factor due to impeding movement (Equation 17-6 or 17-13)	$f_{II8} = 0$	$f_{II11} = 0$
Movement capacity (Equation 17-7)	$c_{mII8} = 0$	$c_{mII11} = 0$
Prob of queue-free state (Equation 17-5)	$p_{0II8} = 0$	$p_{0II11} = 0$
Part III - Single Stage		
Conflicting flows (Exhibit 17-4)	$V_{c8} = 0$	$V_{c11} = 0$
Potential capacity (Equation 17-3 or 17-29)	$c_{p8} = 0$	$c_{p11} = 0$
Ped impedance factor (Equation 17-12)	$p_{p8} = 0$	$p_{p11} = 0$
Capacity adjustment factor due to impeding movement (Equation 17-6 or 17-13)	$f_8 = 0$	$f_{11} = 0$
Movement capacity (Equation 17-7)	$c_{m8} = 0$	$c_{m11} = 0$
Result for Two-Stage Process		
a (Exhibit 17-30)	$a_8 = 0$	$a_{11} = 0$
y (Equation 17-31)	$y_8 = 0$	$y_{11} = 0$
c_T (Equation 17-32 or 17-33)	$c_{T8} = 0$	$c_{T11} = 0$
Prob of queue-free state (Equation 17-5)	$p_{08} = 0$	$p_{011} = 0$

TWSC Unsignalized Intersections

Worksheet 7b

General Information

Project Description: Project Description

Effect of Two-Stage Gap Acceptance

Step 4: LT from Minor Street	v_7	v_{10}
Part I - First Stage		
Conflicting flows (Exhibit 17-4)	$v_{cI7} = 0$	$v_{cI10} = 0$
Potential capacity (Equation 17-3 or 17-29)	$c_{pI7} = 0$	$c_{pI10} = 0$
Ped impedance factor (Equation 17-12)	$p_{pI7} = 0$	$p_{pI10} = 0$
Capacity adjustment factor due to impeding movements	$f_{I7} = 0$	$f_{I10} = 0$
Movement capacity (Equation 17-7)	$c_{mI7} = 0$	$c_{mI10} = 0$
Part II - Second Stage		
Conflicting flows (Exhibit 17-4)	$v_{cII7} = 0$	$v_{cII10} = 0$
Potential capacity (Equation 17-3 or 17-29)	$c_{pII7} = 0$	$c_{pII10} = 0$
Ped impedance factor (Equation 17-12)	$p_{pII7} = 0$	$p_{pII10} = 0$
Capacity adjustment factor due to impeding movements	$f_{II7} = 0$	$f_{II10} = 0$
Movement capacity (Equation 17-7)	$c_{mII7} = 0$	$c_{mII10} = 0$
Part III - Single Stage		
Conflicting flows (Exhibit 17-4)	$V_{c7} = 0$	$V_{c10} = 0$
Potential capacity (Equation 17-3 or 17-29)	$c_{p7} = 0$	$c_{p10} = 0$
Ped impedance factor (Equation 17-12)	$p_{p7} = 0$	$p_{p10} = 0$
Major left, minor through impedance factor	$p''_7 = 0$	$p''_{10} = 0$
Major left, minor through adjusted impedance factor (Equation 17-8)	$p'_7 = 0$	$p'_{10} = 0$
Capacity adjustment factor due to impeding movements (Equation 17-9 or 17-14)	$f_7 = 0$	$f_{10} = 0$
Movement capacity (Equation 17-7)	$c_{m7} = 0$	$c_{m10} = 0$
Result for Two-Stage Process		
a (Exhibit 17-30)	$a_7 = 0$	$a_{10} = 0$
y (Equation 17-31)	$y_7 = 0$	$y_{10} = 0$
c_T (Equation 17-32 or 17-33)	$c_{T7} = 0$	$c_{T10} = 0$

TWSC Unsignalized Intersections

Worksheet 8

General Information

Project Description: Project Description

Shared-Lane Capacity

	v (veh/h)			c_m (veh/h)			
Lane	Movement 7	Movement 8	Movement 9	Movement 7	Movement 8	Movement 9	c_{SH} (veh/H)
1	40	0	120	274	0	750	523
2	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0

SLC_1 =

Lane	Movement 10	Movement 11	Movement 12	Movement 10	Movement 11	Movement 12	
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0

SLC_2 =

Worksheet 9

Effect of Flared Minor-Street Approaches

Lane1 = 0 Lane2 = 0

	Movement 7	Movement 8	Movement 9	Movement 10	Movement 11	Movement 12
c_{sep} (from Worksheet 6 or 7)	0	0	0	0	0	0
volume (from Worksheet 2)	0	0	0	0	0	0
delay (Equation 17-38)	0	0	0	0	0	0
Q_{sep} (Equation 17-34)	0	0	0	0	0	0
Q_{sep} + 1	0	0	0	0	0	0
round(Q_{sep} + 1)	0	0	0	0	0	0

$Results_{9a}$ =

n_{max} (Equation 17-35)	0	0
c_{SH}	0	0
c_{sep}	0	0
n	0	0
c_{act} (Equation 17-36)	0	0

$Results_{9b}$ =

TWSC Unsignalized Intersections

Worksheet 10

General Information

Project Description: Project Description

Control Delay, Queue Length, Level of Service

Lane	Movements	v (veh/h)	c_m (veh/h)	v/c	Queue Length (Eq. 17-37)	Control Delay (Eq. 17-38)	LOS (Exhibit 17-2)	Delay and LOS
1	"7 9 "	160	523	0.306	"< 2"	14.9	"B"	14.9
2	0	0	0	0	0	0	0	"B"
3	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0

$\text{Results}_{101} =$

Movement	v (veh/h)	c_m (veh/h)	v/c	Queue Length (Equation 17-37)	Control Delay (Equation 17-38)	LOS (Exhibit 17-2)
1	0	0	0	0	0	0
4	150	1227	0.122	"< 1"	8.3	"A"

$\text{Results}_{102} =$

Worksheet 11

Delay to Rank 1 Vehicles

	S_2 Approach	S_5 Approach
$p_{0,j}$ (Equation 17-5)	0	0
v_{i1}, volume for Stream 2 or 5	0	0
v_{i2}, volume for Stream 3 or 6	0	0
s_{i1}, saturation flow rate for Stream 2 or 5	0	0
s_{i2}, saturation flow rate for Stream 3 or 6	0	0
$p^*_{0,j}$ (Equation 17-5)	0	0
$d_{\text{major left}}$, delay for Stream 1 or 4	0	0
N, number of major-street through lanes	0	0
$d_{\text{Rank 1}}$, delay for Stream 2 or 5 (Equation 17-39)	0	0

$\text{Results}_{11} =$

AWSC - Unsignalized Intersections

Worksheet 1

General Information

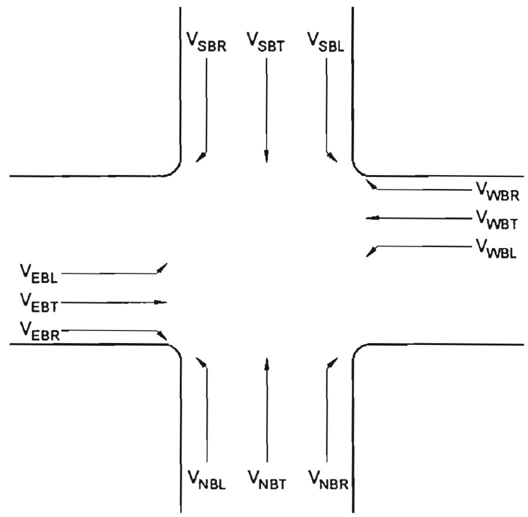
Analyst: Analyst
Agency or Company: Agency or Company
Date Performed: Date Performed
Analyst Time Period: Analyst Time Period

Site Information

Intersection: Intersection
Jurisdiction: Jurisdiction
Analysis Year: Analysis Year

Geometrics and Movements

Length of study period $T := 0.25\,\mathrm{hr}$



Worksheet 2

Volume Adjustments and Lane Assignments

		Lane 1			Lane 2			Geometry Group (Exhibit 17-32)
		LT	TH	RT	LT	TH	RT	
EB	Volume (veh/h)	50	300	0	0	0	0	
	PHF	0	1	0	0	0	0	1
	% Heavy vehicle	0	0	0	0	0	0	
WB	Volume (veh/h)	0	300	100	0	0	0	
	PHF	0	1	0	0	0	0	1
	% Heavy vehicle	0	0	0	0	0	0	
NB	Volume (veh/h)	0	0	0	0	0	0	
	PHF	0	0	0	0	0	0	0
	% Heavy vehicle	0	0	0	0	0	0	
SB	Volume (veh/h)	100	0	50	0	0	0	
	PHF	0	1	0	0	0	0	1
	% Heavy vehicle	0	0	0	0	0	0	

EB	Flow rate (veh/h)	50	300	0	0	0	0
WB	Flow rate (veh/h)	0	300	100	0	0	0
NB	Flow rate (veh/h)	0	0	0	0	0	0
SB	Flow rate (veh/h)	100	0	50	0	0	0

$v =$

AWSC Unsignalized Intersections

Worksheet 3

General Information

Project Description: Project Description

Saturation Headways

	EB L1	EB L2	WB L1	WB L2	NB L1	NB L2	SB L1	SB L2
Total lane flow rate	350	0	400	0	0	0	150	0
Left-turn flow rate in lane	50	0	0	0	0	0	100	0
Right-turn flow rate in lane	0	0	100	0	0	0	50	0
Proportion LT in lane	0.143	0	0	0	0	0	0.667	0
Proportion RT in lane	0	0	0.25	0	0	0	0.333	0
Proportion HV in lane	0	0	0	0	0	0	0	0
h_{LT-adj} (Exhibit 17-33)	0.2	0	0.2	0	0	0	0.2	0
h_{RT-adj} (Exhibit 17-33)	-0.6	0	-0.6	0	0	0	-0.6	0
h_{HV-adj} (Exhibit 17-33)	1.7	0	1.7	0	0	0	1.7	0
h_{adj} (Equation 17-56)	0.029	0	-0.15	0	0	0	-0.067	0

$\text{Results}_3 =$

Worksheet 4a

Departure Headway

	EB L1	EB L2	WB L1	WB L2	NB L1	NB L2	SB L1	SB L2
Total lane flow rate	350	0	400	0	0	0	150	0
h_d, initial value (s)	3.2	0	3.2	0	0	0	3.2	0
x, initial value (Eq. 17-57)	0.311	0	0.356	0	0	0	0.133	0
h_d, Iteration 1	4.471	0	4.256	0	0	0	4.953	0
h_d, difference	1.271	0	1.056	0	0	0	1.753	0
h_d, Iteration 2	4.715	0	4.504	0	0	0	5.316	0
h_d, difference	0.243	0	0.248	0	0	0	0.363	0
h_d, Iteration 3	4.769	0	4.554	0	0	0	5.391	0
h_d, difference	0.054	0	0.05	0	0	0	0.074	0
h_d, Iteration 4	0	0	0	0	0	0	0	0
h_d, difference	0	0	0	0	0	0	0	0
h_d, Iteration 5	0	0	0	0	0	0	0	0
h_d, difference	0	0	0	0	0	0	0	0
Convergence?	"Y"	0	"Y"	0	0	0	"Y"	0
h_d, final	4.769	0	4.554	0	0	0	5.391	0
x, final	0.464	0	0.506	0	0	0	0.225	0

$\text{Results}_{4a} =$

AWSC Unsignalized Intersections
Worksheet 4b

General Information
Project Description: Project Description

Service Time
Approach: EB Lane: 1 Iteration: 1

i	$P(a_{O1})$	$P(a_{O2})$	$P(a_{CL1})$	$P(a_{CL2})$	$P(a_{CR1})$	$P(a_{CR2})$	P(i)	Adj P(i)	P'(i)	h_{base}	h_{adj}	h_{si}	$P'(i)*h_{si}$
1	0.64444	0	0.86667	0	1	0	0.55852	0.00622	0.56474	3.9	0.02857	3.92857	2.21862
2	0.35556	0	0.86667	0	1	0	0.30815	-0.00127	0.30687	4.7	0.02857	4.72857	1.45108
3	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0.64444	0	0.13333	0	1	0	0.08593	-0.0021	0.08382	5.8	0.02857	5.82857	0.48856
7	0.64444	0	0.86667	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0.64444	0	0.13333	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0.35556	0	0.13333	0	1	0	0.04741	-0.00284	0.04456	7	0.02857	7.02857	0.31321
17	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0.35556	0	0.86667	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	0	0	0	0	0
39	0	0	0	0	0	0	0	0	0	0	0	0	0
40	0	0	0	0	0	0	0	0	0	0	0	0	0
41	0	0	0	0	0	0	0	0	0	0	0	0	0
42	0	0	0	0	0	0	0	0	0	0	0	0	0
43	0	0	0	0	0	0	0	0	0	0	0	0	0
44	0	0	0	0	0	0	0	0	0	0	0	0	0
45	0	0	0	0	0	0	0	0	0	0	0	0	0
46	0	0	0	0	0	0	0	0	0	0	0	0	0
47	0	0	0	0	0	0	0	0	0	0	0	0	0
48	0	0	0	0	0	0	0	0	0	0	0	0	0
49	0	0	0	0	0	0	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0	0	0	0	0	0	0
51	0	0	0	0	0	0	0	0	0	0	0	0	0
52	0	0	0	0	0	0	0	0	0	0	0	0	0
53	0	0	0	0	0	0	0	0	0	0	0	0	0
54	0	0	0	0	0	0	0	0	0	0	0	0	0
55	0	0	0	0	0	0	0	0	0	0	0	0	0
56	0	0	0	0	0	0	0	0	0	0	0	0	0
57	0	0	0	0	0	0	0	0	0	0	0	0	0
58	0	0	0	0	0	0	0	0	0	0	0	0	0
59	0	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0	0
61	0	0	0	0	0	0	0	0	0	0	0	0	0
62	0	0	0	0	0	0	0	0	0	0	0	0	0
63	0	0	0	0	0	0	0	0	0	0	0	0	0
64	0.35556	0	0.13333	0	0	0	0	0	0	0	0	0	0

$Results_{4b}$ =

AWSC Unsignalized Intersections

Worksheet 5

General Information

Project Description: Project Description

Capacity and Level of Service

	EB L1	EB L2	WB L1	WB L2	NB L1	NB L2	SB L1	SB L2
Total lane flow rate	350	0	400	0	0	0	150	0
Departure headway, h_d (s)	4.769	0	4.554	0	0	0	5.391	0
Degree of utilization, x	0.464	0	0.506	0	0	0	0.225	0
Move-up time, m (s)	2	0	2	0	0	0	2	0
Service time, t_s (s)	2.769	0	2.554	0	0	0	3.391	0
Capacity (veh/h)	735	0	770	0	0	0	610	0
Delay (s) (Equation 17-55)	11.8	0	12.1	0	0	0	9.9	0
Level of service (Ex. 17-22)	"B"	0	"B"	0	0	0	"A"	0

$\text{Results}_{5a} =$

	EB	WB	NB	SB
Delay, approach (s/veh)	11.8	12.1	0	9.9
Level of service, approach	"B"	"B"	0	"A"

$\text{Results}_{5b} =$

Delay, intersection (s/veh) $d_I = 11.3$

Level of service, intersection $\text{Los}_I = \text{"B"}$

Roundabouts - Unsignalized Intersections

General Information

Analyst: Analyst
Agency or Company: Agency or Company
Date Performed: Date Performed
Analyst Time Period: Analyst Time Period

Site Information

Intersection: Intersection
Jurisdiction: Jurisdiction
Analysis Year: Analysis Year

Volume Adjustments

		EB	WB	NB	SB
	Movement	v_1	v_4	v_7	v_{10}
LT Traffic	Volume (veh/h)	247	103	143	254
	PHF	1	1	1	1
	Movement	v_2	v_5	v_8	v_{11}
TH Traffic	Volume (veh/h)	308	393	207	94
	PHF	1	1	1	1
	Movement	v_3	v_6	v_9	v_{12}
RT Traffic	Volume (veh/h)	105	123	77	152
	PHF	1	1	1	1

LT Traffic	Flow rate (veh/h)	247	103	143	254
TH Traffic	Flow rate (veh/h)	308	393	207	94
RT Traffic	Flow rate (veh/h)	105	123	77	152

V =

Approach Flow Computation

Approach Flow (veh/h) | **v_a (veh/h)**

$v_{aE} := v_1 + v_2 + v_3$ $\quad$ $v_{aE} = 660$

$v_{aW} := v_4 + v_5 + v_6$ $\quad$ $v_{aW} = 619$

$v_{aN} := v_7 + v_8 + v_9$ $\quad$ $v_{aN} = 427$

$v_{aS} := v_{10} + v_{11} + v_{12}$ $\quad$ $v_{aS} = 500$

Circulating Flow Computation

Approach Flow (veh/h) | **v_a (veh/h)**

$v_{cE} := v_4 + v_{10} + v_{11}$ $\quad$ $v_{cE} = 451$

$v_{cW} := v_1 + v_7 + v_8$ $\quad$ $v_{cW} = 597$

$v_{cN} := v_1 + v_2 + v_{10}$ $\quad$ $v_{cN} = 809$

$v_{cS} := v_4 + v_5 + v_7$ $\quad$ $v_{cS} = 639$

Capacity Computation		EB	WB	NB	SB
Capacity (Eq. 17-70)	Upper bound	971	864	728	835
	Lower bound	788	693	573	667
v/c Ratio	Upper bound	0.68	0.716	0.587	0.599
	Lower bound	0.838	0.893	0.745	0.75

Results =

Basic Freeway Segments Worksheet

General Information

Analyst: Analyst
Agency or Company: Agency or Company
Date Performed: Date Performed
Analysis Time Period: Analysis Time Period

Site Information

Highway/Direction of Travel: Highway/Direction
From/To: From/To
Jurisdiction: Jurisdiction
Analysis Year: Analysis Year
Freeway segment area: ○ Rural ○ Urban

☑ Operational (LOS) ☐ Design (N) ☐ Design (Vp) ☐ Planning (LOS) ☐ Planning (N) ☐ Planning (Vp)

Flow Inputs

Volume: $V := 2000 \frac{veh}{hr}$

Annual avg. daily traffic: $ADDT := 0 \frac{veh}{day}$

Peak-hour proportion of ADDT: $K := 0 \frac{day}{hr}$

Peak-hour direction proportion: $D := 0$

Directional design-hour volume:

$DDHV := ADDT \cdot K \cdot D$ $DDHV = 0 \frac{veh}{hr}$

Driver type: ○ Commuter/Weekday ○ Recreational/Weekend

Peak-hour factor: $PHF := 0.92$

% Trucks and buses: $P_T := 5$

% RVs: $P_R := 0$

General terrain: Level

Grade: None

$Length := 0mi$

$UpDown := 0\%$

Calculate Flow Adjustments

Driver population factor: $f_p := 1$

Passenger-car equivalents for truck/buses: $E_T = 1.5$

Passenger-car equivalents for RVs: $E_R = 1.2$

Heavy-vehicle adjustment factor: $f_{HV} := \frac{1}{1 + P_T \cdot (E_T - 1) + P_R \cdot (E_R - 1)}$ $f_{HV} = 0.976$

Speed Inputs

Lane width $Lw := 11ft$
Rt.-shoulder lateral clearance $Rslc := 2ft$
Interchange density $Id := 1 \frac{I}{mi}$
Number of lanes $N := 2$
Free-flow speed (measured) $FFS := 0mph$
Base free-flow speed $BFFS := 75mph$

Calculate Speed Adjustments and FFS

Adjustment for Lane Width (Exhibit 23-4): $f_{LW} = 1.9\,\text{mph}$

Adjustment for Right-Shoulder Lateral Clearance (Exhibit 23-5): $f_{LC} = 2.4\,\text{mph}$

Adjustment for Interchange Density (Exhibit 23-7): $f_{ID} = 2.5\,\text{mph}$

Adjustment for Number of Lanes (Exhibit 23-6): $f_N = 0\,\text{mph}$

FSS = BFFSS - f_{LW} - f_{LC} - f_{ID} - f_N $\quad$ $FFS = 68.2\,\text{mph}$

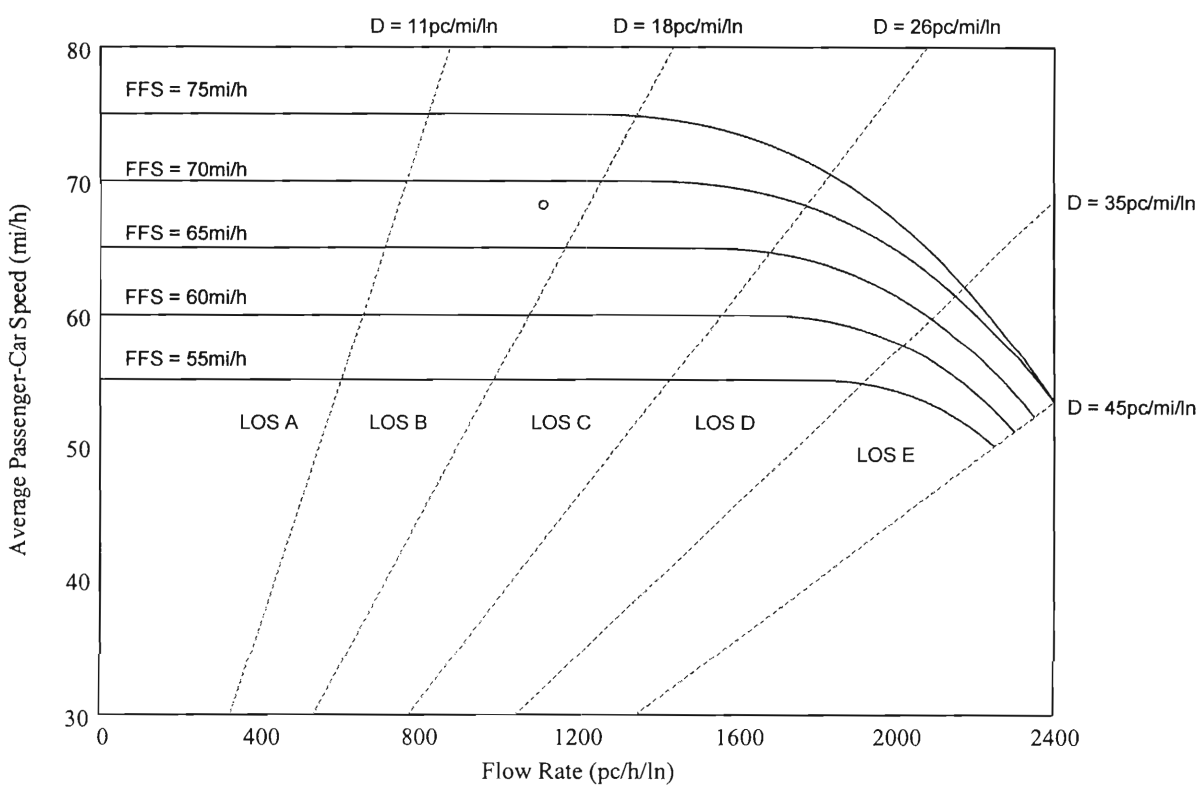
LOS and Performance Measures

Flow rate: $V_p = \dfrac{VorDDHV}{PHF \cdot N \cdot f_{HV} \cdot f_p}$ $\quad$ $V_p = 1114\,\dfrac{pc}{hr \cdot ln}$

Average passenger-car speed: $S = 68.2\,\text{mph}$

Density: $D := \dfrac{V_p}{S}$ $\quad$ $D = 16.3\,\dfrac{pc}{mi \cdot ln}$

Level of service: LOS = "B"



Note: to see all the annotations, right-click on the graph and choose "Send to Back"

Ramps and Ramps Junctions Worksheet

General Information

Analyst: Analyst
Agency or Company: Agency or Company
Date Performed: Date Performed
Analyst Time Period: Analyst Time Period

Site Information

Freeway/Direction of Travel: Freeway/Direction of Travel
Junction: Junction
Jurisdiction: Jurisdiction
Analysis Year: Analysis Year

☑ Operational (LOS) ☐ Design (LA, LD or N) ☐ Planning (LOS) ☐ Planning (LA, LD or N)

Inputs

Upstream Adjacent Ramp

○ Yes ○ On
◉ No ○ Off

$L_{up} := 0ft$

$V_U := 0 \frac{veh}{hr}$

Terrain: Level

Number of lanes on freeway segment (one direction): $N_F := 2$
Number of lanes on ramp: $N_R := 1$
Acceleration lane length (outer): $L_{Ao} := 0ft$
Acceleration lane length (inner)*: $L_{Ai} := 750ft$
Deceleration lane length (outer): $L_{Do} := 0ft$
Deceleration lane length (inner)*: $L_{Di} := 0ft$

Side of ramp: ◉ Right-hand ○ Left-hand

Area Type: ◉ Merge Areas ○ Diverge Areas

$S_{FF} := 60mph$ $S_{FR} := 45mph$

Downstream Adjacent Ramp

○ Yes ○ On
◉ No ○ Off

$L_{down} := 0ft$

$V_D := 0 \frac{veh}{hr}$

* For single-lane ramps, enter the length of the acceleration or deceleration lane on the "inner" option.

Conversion to pc/h Under Base Conditions

(pc/h)	AADT (veh/day)	K	D	V (veh/h)	PHF	%HV	f_p
v_F	0	0	0	2500	0.9	10	1
v_R	0	0	0	550	0.9	5	1
v_U	0	0	0	0	0	0	0
v_D	0	0	0	0	0	0	0

(pc/h)	f_{HV}	v (pc/h)
v_F	0.952	2917
v_R	0.976	626
v_U	0	0
v_D	0	0

Results =

Note: f_{HV} and v cannot be displayed in the same table along with the rest of the parameters (as in the HCM worksheet), because f_{HV} and v depend on those parameters.

Merge Areas

Estimation of v_{12}

$$v_{12} = v_F \cdot P_{FM}$$

$L_{EQm} = 0$ (Equation 25-2 or 25-3)

$P_{FM} = 1$ using $\text{Equation}_m = 0$ (Exhibit 25-5)

$v_{12m} = 2917 \frac{pc}{hr}$

$v_{23m} = 0 \frac{pc}{hr}$

$v_{34m} = 0 \frac{pc}{hr}$

Diverge Areas

Estimation of v_{12}

$$v_{12} = v_R + (v_F - v_R) \cdot P_{FD}$$

$L_{EQd} = 0$ (Equation 25-8 or 25-9)

$P_{FD} = 0$ using $\text{Equation}_d = 0$ (Exhibit 25-12)

$v_{12d} = 0 \frac{pc}{hr}$

$v_{23d} = 0 \frac{pc}{hr}$

$v_{34d} = 0 \frac{pc}{hr}$

Note: the display of v_{23} and v_{34} is additional to the HCM worksheet

Capacity Checks (Merge)

	Actual	Maximum	LOS F?
V_{FO}	3543	4600	"No"
V_{R12}	3543	4600	"No"

$\text{CapacityChecks}_m =$

Capacity Checks (Diverge)

	Actual	Maximum	LOS F?
V_{FI}	0	0	0
V_{12}	0	0	0
V_{FO}	0	0	0
V_{R12}	0	0	0

$\text{CapacityChecks}_d =$

Level-of-Service Determination (if not F)

$$D_R = 5.475 + 0.00734\, v_R + 0.0078\, v_{12} - 0.00627\, L_A$$

$D_{Rm} = 28.1 \frac{pc}{mi \cdot ln}$

$LOS_m = \text{"D"}$ (Exhibit 25-4)

Level-of-Service Determination (if not F)

$$D_R = 4.252 + 0.0086\, v_{12} - 0.009\, L_D$$

$D_{Rd} = 0 \frac{pc}{mi \cdot ln}$

$LOS_d = 0$ (Exhibit 25-4)

Speed Estimation

$M_S = 0.388$ (Exhibit 25-19)

$S_{Rm} = 53\ mph$ (Exhibit 25-19)

$S_{Om} = 0\ mph$ (Exhibit 25-19)

$S_m = 53\ mph$ (Exhibit 25-14)

Speed Estimation

$D_S = 0$ (Exhibit 25-19)

$S_{Rd} = 0\ mph$ (Exhibit 25-19)

$S_{Od} = 0\ mph$ (Exhibit 25-19)

$S_d = 0\ mph$ (Exhibit 25-15)

Transit

BUS FACILITIES

Dwell Time

Inputs

Bus type: Conventional (rigid bod

Number of available doors or channels: $Nd := 2$

Location of doors or channels: Front

Number of seats: $Sn := 42$

Door opening and closing time: $t_{oc} := 4 \cdot s$

Boarding time per passenger: $t_b := 3 \cdot s$

Alighting time per passenger: $t_a := 2 \cdot s$

Stop number	1	2	3	4	5	6	7	8	9	10				
Alighting passengers	0	0	3	2	14	6	16	19	15	11				
Boarding passengers	20	16	11	12	16	8	2	1	0	0				

Results

Results =

Stop number	1	2	3	4	5	6	7	8	9	10
Seated	20	36	42	42	42	42	42	26	11	0
Standees	0	0	2	12	14	16	2	0	0	0
Boarding time (s)	60	48	38.5	42	56	28	7	3	0	0
Alighting time (s)	0	0	6	4	28	12	32	38	30	22
Dwell time (s)	64	52	42.5	46	60	32	36	42	34	26

Bus Vehicle Capacity

Inputs

Type of facilities:	Exclusive Urban Stre
Number of lanes:	$N := 3$
Signalized intersections:	$Si := 4$
Effective green time per signal cycle:	$gC := 0.45$
Cycle length:	$Cl := 90 \cdot s$
Buses per hour that will use the street:	$Bh := 40$
Automobiles per hour that will use the street:	$Ah := 1200$
Loading areas per stop:	$La := 2$
Location of loading areas:	On-Line
Bus stop location:	Near-side
Bus lane type:	Type 1
Conditions of stops:	Stops every block
Type of arrivals:	Random
Base saturation flow rate:	$s_0 := 1900 \cdot \frac{pc}{hr \cdot ln}$
Bus blockage factor:	$f_{bb} := 0.84$
Area factor:	$f_a := 0.9$
Clearance time:	$t_c := 10 \cdot s$
Failure rate:	$Fr := 7.5\%$
Coefficient of variation of dwell times:	$c_v := 60\%$

Stop number	1	2	3	4
Dwell time (s)	30	35	40	20
Curb lane right-turn auto volume (veh/h)	350	200	100	300
Curb lane through auto volume (veh/h)	50	100	100	50
Conflicting ped volume (p/h)	100	300	500	200
f_{Rpb}	0.948	0.898	0.883	0.908
f_{HV}	1	1	1	1
Bus lane vehicle capacity (buses/h)*	34	34	36	49

***Note:** input the bus lane vehicle capacity when the stops conditions are alternating 2-block stops or alternating 3-block stops.

Results

Results =

Stop number	1	2	3	4
P_{RT}	0.795	0.588	0.417	0.769
Right-turn saturation adjustment factor, f_{RT}	0.881	0.912	0.938	0.885
Pedestrian adjustment factor for right-turn movements, f_{Rpb}	0.948	0.898	0.883	0.908
Heavy-vehicle factor, f_{HV}	1	1	1	1
Right-turn lane capacity, c_r (veh/h)	540	529	535	519
Curb lane capacity, c_c (veh/h)	540	529	535	519
Adjacent lane capacity, c_a (veh/h)	0	0	0	0
Right-turn lane volume, v_r (veh/h)	350	200	100	300
Curb lane volume, v_c (veh/h)	440	340	240	390
Adjacent lane volume, v_a (veh/h)	0	0	0	0
Right-turn adjustment factor, f_r	0.351	0.622	0.813	0.422
Mixed-traffic adjustment factor, f_m	0	0	0	0
Adjacent lane impedance factor, a	0	0	0	0
Capacity adjustment factor for skip-stop operations, f_k	0	0	0	0
Maximum number of buses per berth per hour, B_{bb} (buses/h)	33	29	26	45
Bus lane capacity, B (buses/h)	21	33	39	35

Bus Person Capacity

Inputs

Number of seats: $Sn := 43$

Number of buses that not allow standees: $Nbns := 10$

Number of buses that allow standees: $Nbys := 30$

Load factor: $Lf := 1.5$

Peak-hour factor: $PHF := 0.75$

Results

Bus person capacity: $P = 1774p$

Average Speed of Buses

Inputs

Block length: $Bl := 400ft$

Volume in adjacent lane: $v := 400\frac{veh}{hr}$

Vehicular capacity of adjacent lane: $c := 985\frac{veh}{hr}$

Volume of buses in bus lane: $v_b := 40\frac{buses}{hr}$

Bus vehicle capacity: $c_b := 48\frac{buses}{hr}$

Bus running time losses: $t_{r1} := 3.8\frac{min}{mi}$

Bus-bus interference adjustment factor: $f_b := 1$

Results

Stop frequency: $SF = 13.2\frac{stops}{mi}$

Base bus running time: $t_{r0} = 14.477\frac{min}{mi}$

Skip-stop speed adjustment factor: $f_s = 1$

Bus travel speed: $S_t = 3.3\frac{mi}{hr}$

LIGHT RAIL AND STREETCAR FACILITIES

Inputs

General Inputs

Number of cars per train: $C_t := 1$

Block length $Bl := 450ft$

Peak-hour loading service standard: $PHL := 1.5 \cdot \frac{p}{ft}$

Dwell Time Inputs

Dwell time: Known

$t_d := 35s$

Number of channels per door for moving passengers: $N_{cd} := 0$

Door opening and closing time: $t_{oc} := 0s$

Alighting passengers per rail through busiest door: $P_d := 0p$

Type of car entry: Level

Flow classification: Mainly Boardin

Number of doors per car: $D_c := 1$

Number of cars per train: $N_c := 1$

Scheduled headway: $h_s := 30s$

Maximum person capacity: $P := 0p$

Peak-hour factor : $PHF := 0.75$

Ratio of busiest door usage to average door usage: $R_d := 0$

Minimum Headways Inputs

Effective green time per signal cycle: $gC := 0.5$

Maximum cycle length in line's on-street section: $C_{max} := 90s$

Clearance time between successive trains: $t_c := 27.7s$

Failure rate: $Fr := 25\%$

Coefficient of variation of dwell times: $c_v := 40\%$

Time to cover single-track section: $t_{st} := 0s$

Length of single-track section: $L_{st} := 0ft$

Train length: $L := 0ft$

Car length: $L_c := 90ft$

Number of stations on single-track section: $N_s := 0$

Maximum speed reached: $S_{max} := 0 \frac{ft}{s}$

Deceleration rate:	$d_s := 0\frac{ft}{s^2}$
Initial acceleration:	$a_s := 3\frac{ft}{s^2}$
Jerk-limiting time:	$t_{jl} := 0s$
Operator and braking system reaction time:	$t_{br} := 0s$
Speed margin:	$SM := 0$
Operating margin time:	$t_{om} := 0s$
Minimum block-signaled section train headway:	$h_{bs} := 0s$

Light Rail and Streetcar Capacity Inputs

Analysis section length:	$L_{as} := 0mi$
Free-flow speed of train:	$S_f := 0\frac{mi}{hr}$
Number of stops or stations in analysis section:	$N := 0$

Results

Dwell Time:	$t_d = 35s$
Number of doors available in peak hour:	$D = 120$
Passenger volume through busiest door:	$P_d = 0p$
Minimum on-street section train headway:	$h_{os} = 120s$
Minimum single-track section train headway:	$h_{st} = 0s$
Time to cover single-track section:	$t_{st} = 0s$
Maximum number of trains per hour:	$T = 30$
Maximum person capacity:	$P = 3038p$
Running time:	$t_r = 0s$
Acceleration and deceleration time:	$t_a = 0s$
Total travel time:	$t_t = -35s$
Average travel speed:	$S_t = 0\frac{mi}{hr}$